470

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

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ABSTRACTS OF PAPERS,

AND

REPORTS OF THE PROCEEDINGS

OF

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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WILLIAM LASSELL, Esq., F.R.S., President, in the Chair.

Josh. H. Freeman, Esq., Stratford House, Stratford;
R. Holford M. Bosanquet, Esq., St. John's College, Cambridge; and
Harry Taylor, Esq., Avenue Road, Regent's Park,

were balloted for and duly elected Fellows of the Society.

Note on the Construction of the Heavens, explanatory of a Chart of 324,198 *Stars.* By Richard A. Proctor, B.A. (Cambridge).

It is well known that, according to the theory of the universe enunciated by Sir W. Herschel in 1785,—that theory which is commonly, but erroneously, described as the outcome of his labours amid the star-depths,—the stars visible to the unaided eye are included within a space which bears an exceedingly minute proportion to the dimensions of the Galaxy itself. Herschel's original drawing of a section of the Galaxy—as conceived by him in 1785—is before me as I write. It extends across a folding sheet in a quarto volume. On the same scale, he says, the distance of the nearest fixed star would be no more than the 80th part of an inch, "so that probably all the stars which in the finest nights we are able to distinguish with the naked eye may be comprehended within a sphere," in the middle of this picture of our Galaxy, "*of less than half a quarter of an inch radius.*"

It was with reference to this view that in a paper called

"Notes on Star Streams," which appeared in the *Intellectual Observer* for August 1867, I pointed out that the stars of the first five orders of magnitude, only, show too marked a tendency to follow the direction of that great star-stream, the Milky Way, for the flat-disk theory to be admissible. I then noted,—and I am careful to mention the point, because objections have been urged which would imply that I had forgotten it,—that the first five orders of stars could give but very imperfect evidence *if* the accepted views about star distribution were just. But "it is on on that very fact," I added, "that I wish to dwell. If any connexion *does* appear between the configuration of our Galaxy, and the arrangement of stars which are assumed to be much nearer to us than the Milky Way, it will be obvious that we must somewhat modify our views."

I was not then aware that the astronomer Piazzi had noted the same fact,—though he had dealt rather with statistical evidence than with the more direct evidence I adduced from my star-charting. Nor was I then aware that Struve had followed up Piazzi's hint in the introduction to the *Catalogus Regiomontanus*, and that he had been led to precisely my own conclusion,—viz., that the observed distribution of the stars of the leading orders of magnitude is incompatible with the accepted or text-book theory of the Sidereal System. Still less was I then aware, though I had carefully read through all Sir W. Herschel's papers on the heavens, that in his later papers he virtually abandoned the theory of 1785. This fact had wholly escaped my notice, as I believe it escapes the notice of nearly all who give to those papers but a single perusal, however carefully that perusal may be made. It was only on a careful re-investigation of the whole series of Sir W. Herschel's papers (well worth and indeed requiring many readings) that I observed how completely his views changed some fifteen years or so after the enunciation of the theory of 1785. Somewhat later I found that Struve had been led, by a second reading of Herschel's papers, to a similar conclusion. For, in his *Etudes d'Astronomie Stellaire*, in which he extended his statistical inquiries to stars down to the 9th magnitude, he remarks that he "had been chiefly led to this ulterior discussion by a re-examination (*une nouvelle étude*) of the memoirs of Sir W. Herschel," which "has led me to the conviction," he adds, "that my actual ideas respecting the Milky Way are only opposed to Herschel's theory of 1785, but agree very well with the latter views (*sont extrêmement conformes aux vues postérieures*) of that great astronomer."

The researches I am now dealing with may be regarded as an extension of Struve's inquiry; only that whereas he employed a method of statistical research, I have preferred the method of actual charting to which I have adhered throughout these inquiries—whether I have dealt with stars or nebulæ. I believe that star-charting, appealing as it does directly to the eye, and presenting not only general features, but those minor details

which the statistician is obliged to neglect, is well worth the increased labour which it involves.

In order that the bearing of the present inquiry on Struve's, as well as on the Herschelian star-guages, may be rightly apprehended, it will be as well to note what Struve and the Herschels actually accomplished, the more so that mistaken notions are very prevalent on the subject.

For instance, with respect to the star-guagings, the opinion is not uncommonly entertained that the whole sphere of the heavens was surveyed or guaged by the Herschels. Many persons seem unaware of the fact that such a survey would have been quite impracticable even though these great astronomers had been able and willing to give their whole time to the work. When we remember that the labour actually bestowed by the Herschels on their star-guagings bore but a minute proportion to that which they bestowed on other and more difficult researches, we need not be surprised to find that the portion of the heavens actually guaged was exceedingly small compared with the whole surface of the celestial sphere. To afford an idea of the real extent of the Herschelian guages, the following illustration may be employed:—If the whole surface of the celestial sphere be represented by the surface of an ordinary chess-board, then all the guage-fields of Sir W. Herschel taken together (though 3400 in number) correspond to but about the fourth part of one of the squares; while the guage-fields surveyed by Sir John Herschel, taken together, correspond to somewhat less than a fifth part of one of the squares. Again, all the stars actually counted by Sir W. Herschel during his star-guaging amounted to about 90,000; those counted by Sir John Herschel to about 70,000: in all about 160,000. Now Struve estimates the total number of stars visible with the Herschelian guaging telescopes at upwards of 20 millions; so that the number actually counted is less than the 120th part of those which would have come into view in a complete survey. To this I may add that Sir W. Herschel, speaking of his 3400 guages, says that he regards them as "only an example to illustrate the spirit of the method."

Struve's latest and most extensive series of inquiries was applied to a list of 31,085 stars occupying a zone of the heavens between 15° north and 15° south of the equator, covering, therefore, a space equal to about the fourth part of the celestial sphere. By a series of ingenious inquiries into the number of stars probably missed in various parts of this zone, Struve virtually increased the number of stars he dealt with from about 31,000 to about 52,000.

The method he then adopted in dealing with these stars was simply this: he divided the great equatorial zone over which they were spread into hours of right ascension, and compared the numbers of stars in these divisions. He regarded these numbers as fairly indicating the richness of star-distribution *round the equator itself, compressing* (*as it were*) *a zone* 30° *wide into an*

indefinitely thin equatorial ring. Finally, *he converted this equatorial ring into an equatorial disc, by conceiving the stars of the various orders of magnitude to be distributed at corresponding distances from the centre of the celestial sphere.*

With all respect for the eminent abilities of the great Russian astronomer, I venture to point out that there are very grave objections to his method of research. The spaces into which he divided the heavens were inordinately large: each, in fact, extending 15° in right ascension and 30° in polar distance. To take averages for divisions so extensive must surely be regarded as unsatisfactory.

Moreover, the Galaxy, regarded by Struve as a zone of stellar concentration, runs obliquely across his wide equatorial zone, a circumstance obviously tending to render his results less instructive than they might otherwise have been. He notes this himself in accounting for the absence in his statistical results of all signs of the division of the Galaxy.

Lastly, as the main result of Struve's inquiries was to exhibit the want of uniformity in stellar distribution *over* the equatorial zone, his assumption of a uniform distribution *in the plane of* the equatorial disc, must be regarded as venturesome in the extreme.

As respects the construction of the chart which I now have the pleasure of exhibiting to this Society,* I need here say little, because I have elsewhere adverted to the points which seem of chief importance. I would note, however, that the pencilled divisions on this projection represent spaces on the sphere averaging in extent one 280th part, only, of those into which Struve divided his equatorial zone. Each space, also, was filled in, *not* according to the mere number of stars, but very carefully by an eye-draught from the corresponding space in Argelander's charts. That I might not be influenced by the natural tendency (as Sir John Herschel calls it) to "exaggerate any peculiarity which might at the moment seem a feature," each meridional sector, 5° wide, was covered over as soon as it was completed. The work when once commenced was carried on without intermission (except for rest and food), all other work being set aside. The necessity for this will be obvious when it is remembered that if the work had been left even for a few days only, the probability is that on returning to it I might have somewhat modified the scale of star-magnitudes, a circumstance which would have rendered all the work valueless. Even as it was, I found continual watchfulness necessary lest any change in the style of the work should be unwittingly admitted. It is not easy to work at a star-map for six or seven weeks in succession without

* Owing to a mistake on the part of the frame-maker, the original chart was not exhibited at the Meeting. Mr. Brothers obligingly supplied the defect by exhibiting a negative 8 inches in diameter. The original chart (25 inches in diameter) will be shown at the next Meeting.

changing the style or character of the charting; and I found it quite impossible to complete the chart in less than six or seven weeks. In fact, it is only necessary to compute the time required for marking in the stars to see that the work could not readily be compressed into a shorter interval of time. At the moderate rate of one minute for ten stars, 32,400 minutes, or 540 hours would be required; but the time actually occupied amounted only to 400 hours. I was pleased to find that along the line in which the last day's work was brought up to the first day's, no signs of any change in the style of mapping could be noticed. Had the star-magnitudes been enlarged or diminished in the interval, a sharp line of demarcation would unquestionably have been recognisable. As it is, I think I may defy the acutest observer to determine along what radial line the work began and ended.

So much being noted, in order that the trustworthiness of the chart may be sufficiently established, I will now briefly sum up the results to which the careful study of the chart appears to lead.

In the first place, Struve's general conclusion that the stars of the first nine or ten orders of magnitude are more densely aggregated along the galactic zone is abundantly justified.* But instead of a gradual increase of density such as his statistics suggested, we recognise in the chart a distinctly marked aggregation within those very regions of the heavens where the Milky Way is brightest to the eye. In other words, we have clear evidence that it is not towards a certain *zone* that the stars are gathered, but into those irregular cloudlike masses, those streams, projections, and interlacing branches which constitute the Milky Way, as it is actually presented on clear nights to our study.

Let me quote here—in correction of that account of the Milky Way which is too often presented in our text-books—the description which Prof. Nichol has given of that wonderful star region. "It is, indeed, only to the most careless glance," he justly says, "or when viewed through an atmosphere of imperfect transparency, that the Milky Way seems a continuous zone. Let the naked eye rest thoughtfully on any part of it, and if circumstances be favourable, it will stand out rather as an accumulation of patches and streams of light of every conceivable variety of form and brightness; now side by side; now heaped on each other; again spanning across dark spaces, intertwining, and forming a most curious and complex net-work; and at other times darting off into the neighbouring skies in branches of capricious length and shape, which gradually thin away and disappear."

* It is to be noticed that Argelander's magnitudes differ from those employed by Sir John Herschel. According to the nomenclature of the English astronomer my chart includes all stars down to the eleventh magnitude inclusive.

It will be seen that the aspect of the star-groups in the chart accords in the most significant manner with this description.

I would note, next, a circumstance which at first somewhat surprised me. The densely crowded regions in the chart show certain very well-marked projections in *Perseus* and *Auriga*, on the northern side of the Galaxy. Sir John Herschel, in his account of the Milky Way, mentions no such projections. But something in the aspect of these projecting masses seemed familiar to me so soon as I studied the complete chart. At length I was led to examine the Milky Way as depicted in the maps constructed by Sir John Lubbock. In my Gnomonic charts I had followed that figure of the Galaxy, and I had used the same delineation in a work now out of print, called the *Constellation Seasons*. On turning to my own drawings in these works, I found the very projections whose appearance had seemed familiar to me, as well as a long projection on the southern side of the Milky Way in *Perseus*, extending from *Algol* towards *Andromeda*. This projection also follows the direction of a declination-parallel, and its form is very clearly to be recognised in the chart. In the key-map I have shown these projections on opposite sides of the Milky Way in *Perseus*.

In the chart, however, we see these projections carried much further away from the main branch. We see, also, that from the other half of the Milky Way between *Cepheus* and *Aquila* there are similar extensions curving round on the northern side to a considerable distance from the main branch. One of these traverses *Lyra* and curves round almost to *Ursa Major;* another passes round from *Hercules* to *Corona;* while we note that the discontinuous branch which the naked eye recognises as extending from *Cygnus* to *Ophiuchus* is carried round towards *Boötes*.

Amongst these branching extensions there is, in places, so singular a tendency to agreement with declination-parallels, that the question may well suggest itself whether the peculiarity is not due to some feature in the construction of the maps—some bias, as it were, by which I might have been led to parallelize the star-grouping in this particular way; for plainly the north pole of the sky has no relation whatever to the construction of the stellar heavens. I am able to assert, however, with the utmost certainty of conviction, that nothing in the construction of the maps can explain the peculiarity. The original chart was most carefully divided into 26,400 spaces, each very small therefore, and the average number of stars to each space was but eighteen. These spaces were severally much smaller, both in length and breadth, than the cross-section of these branching extensions; so that even the most unpractised draughtsman, working in the most careless manner, could not have been so biassed that these curved branches could be thus explained away. As I have had some degree of practice in star-charting, and as, further, every portion of this chart was drawn as though it were forthwith to be subjected to the severest and most critical scrutiny, it will be understood how

utterly impossible it is that so marked a peculiarity can have the imagined explanation.*

Apart from this, the curved branches will be found, on a close scrutiny, not to agree exactly with the direction of declination-parallels; and all of them can be traced in Argelander's large charts, when these are carefully studied.

A circumstance of some interest is to be recognised in the fact that these branching extensions are found to lead, in almost every instance, towards regions of the heavens where many nebulæ exist.

The rich stellar region of *Orion*, as well as the *Hyades* and *Pleiades*, are shown to be intimately associated with the Milky Way.

In conclusion, I may remark that although the results to which this chart seems to point may appear altogether opposed to accepted views respecting the construction of the heavens, they accord exceedingly well with the enlarged views formed by Sir W. Herschel towards the close of his career as an observer,† and even better with the views towards which his later researches *pointed*. The mode of research I have adopted is altogether new, and it is one which seems more likely to lead to clear views of the construction of the heavens than any yet employed; for it presents before the eye at one view what hitherto has had to be inferred from tabulated figures. It is capable of a far wider extension, however; and I could wish that others who have more leisure than I can afford would aid in this interesting branch of inquiry. To such I would repeat the words by which Sir John Herschel, two years ago, encouraged me to fresh inquiries: "Be not deterred," he wrote on August 1, 1869, "from dwelling closely and consecutively on these inquiries, by any idea of their hopelessness which the objectors against 'paper astronomy' may entertain, or by the real slenderness of the material threads out of which any connected theory of the universe has at present to be woven."

Brighton, 8 *Nov.* 1871.

Extract of a Letter from E. J. Stone, Esq., to the Astronomer Royal, dated Royal Observatory, Cape of Good Hope, Sept. 30, 1871.

"I had hoped to have been able to forward the Catalogue for 1858 and 1859 by this mail, but my work has been nearly stopped through illness [of some of the Assistants]. The year 1859 is much richer in Southern stars than the other years. I hope to have the years 1857, 1858, and 1859 ready for press within a month."

* This does not preclude the possibility that there may be in places a tendency to "meridional" or "parallel" *graining*, so to speak; but of a much finer nature than the peculiarity referred to in the text, and in no way affecting the chart's real significance.

† I except the papers of 1817 and 1818.

On the Expression of Delaunay's l, g, h, in terms of his finally adopted Constants. By Prof. Cayley.

We have in Delaunay's lunar theory,—

l, the mean anomaly of the Moon,
g, the mean distance of perigee from ascending node,
h, the mean longitude of ascending node,

quantities which vary directly as the time, the coefficients of t, or values of $\frac{dl}{dt}, \frac{dg}{dt}, \frac{dh}{dt}$, being given in his *Théorie du Mouvement de la Lune*, vol. ii. pp. 237, 238. But these values are not expressed in terms of his constants a (or n), e, γ, finally adopted as explained p. 800, and it seems very desirable to obtain the expressions of l, g, h, in terms of these finally adopted constants: I have accordingly effected this transformation (which I found less laborious than I had anticipated). It will be convenient to imagine the a, n, e, γ of pp. 237, 238 replaced by A, N, E, Γ respectively. This being so, and writing m for the $\frac{n}{n'}$ of p. 800 we have, p. 800,—

$$\begin{aligned}
\mathrm{A} = a \Big\{ & 1 + \left[-\frac{3}{4} m^2 - \frac{825}{256} m^3 \right] \frac{a^2}{a'^2} \\
& + \left(-\frac{2}{3} + 3\gamma^2 - \frac{3}{4} e^2 - e'^2 - 2\gamma^2 + \frac{5}{2}\gamma^2 e^2 + \frac{9}{2}\gamma^2 e'^2 - \frac{1}{16} e^4 - \frac{9}{8} e^2 e'^2 - \frac{5}{4} e'^4 \right) m^2 \\
& + \left(-\frac{9}{4}\gamma^2 - \frac{225}{16} e^2 + \frac{45}{8}\gamma^4 + \frac{81}{2}\gamma^2 e^2 - \frac{23}{4}\gamma^2 e'^2 + \frac{675}{128} e^4 - \frac{825}{16} e^2 e'^2 \right) m^3 \\
& + \left(\frac{1705}{288} - \frac{1529}{64}\gamma^2 - \frac{14639}{256} e^2 + \frac{7469}{192} e'^2 \right) m^4 \\
& + \left(\frac{787}{48} - \frac{9323}{256}\gamma^2 - \frac{227555}{1024} e^2 + \frac{7083}{32} e'^2 \right) m^5 \\
& + \frac{5887}{162} m^6 \\
& + \frac{29809}{432} m^7
\end{aligned}$$

and hence calculating N from the formula $\mathrm{N}^2 \mathrm{A}^3 = n^2 a^3$, we find

$$\mathrm{N} = n \left\{ 1 + \left[\frac{9}{8} m^2 + \frac{2475}{512} m^3 \right] \frac{a^2}{a'^2} \right.$$

$$+\left(1-\frac{3}{2}\gamma^2+\frac{3}{8}e^2+\frac{3}{2}e'^2+3\gamma^4-\frac{15}{4}\gamma^2e^2-\frac{27}{4}\gamma^2e'^2+\frac{3}{32}e^4+\frac{27}{16}e^2e'^2+\frac{15}{8}e'^4\right)m$$
$$+\left(\frac{27}{8}\gamma^2+\frac{675}{32}e^2-\frac{135}{16}\gamma^4-\frac{243}{4}\gamma^2e^2+\frac{69}{8}\gamma^2e'^2-\frac{2025}{256}e^4+\frac{2475}{32}e^2e'^2\right)m^3$$
$$+\left(-\frac{515}{64}+\frac{3627}{128}\gamma^2+\frac{44877}{512}e^2-\frac{7149}{128}e'^2\right)m^4$$
$$+\left(-\frac{787}{32}+\frac{30849}{512}\gamma^2+\frac{754665}{2048}e^2-\frac{21249}{64}e'^2\right)m^5$$
$$+\left(-\frac{13183}{192}\right)m^6$$
$$+\left(-\frac{20807}{144}\right)m^7.$$

$=n(1+Q)$ suppose $\therefore$.

The values of E, Γ are given p. 800, but for the present purpose we only require E^2, and Γ^2 to the fifth order, viz. the values of these are at once found to be

$$E^2=e^2\left(1+\frac{81}{64}m^2-\frac{2595}{128}m^3\right)$$
$$\Gamma^2=\gamma^2\left(1+\frac{57}{64}m^2-\frac{129}{128}m^3\right)$$

whence also $E^4=e^4$ and $\Gamma^4=\gamma^4$.

The formulæ of pp. 237–238 now give

$$l=nt\left\{1+\left[-\frac{81}{32}m^2-\frac{2475}{512}m^3\right]\frac{a^2}{a'^2}+Q\right.$$
$$\left.+\left\{\begin{array}{l}\left(-\frac{7}{4}+\frac{21}{2}\gamma^2-\frac{3}{4}e^2-\frac{21}{8}e'^2+\frac{33}{4}\gamma^4-\frac{39}{8}\gamma^2e^2+\frac{63}{4}\gamma^2e'^2-\frac{9}{8}e^2e'^2-\frac{105}{32}e'^4\right)m^2\\+\left(\frac{1197}{128}\gamma^2-\frac{243}{256}e^2\right)m^4\\+\left(-\frac{2709}{256}\gamma^2+\frac{7785}{512}e^2\right)m^5\end{array}\right\}(1+Q)^{-}$$

$$+\left\{\begin{array}{l}\left(-\frac{225}{32}+\frac{81}{4}\gamma^2-\frac{675}{64}e^2-\frac{825}{32}e'^2-\frac{243}{4}\gamma^4+\frac{1863}{32}\gamma^2e^2+\frac{629}{8}\gamma^2e'^2+\frac{2025}{256}e^4-\frac{2475}{64}e^2e'^2\right)m^3\\ \qquad+\left(\frac{4617}{256}\gamma^2-\frac{54675}{4096}e^2\right)m^5\end{array}\right\}(1+Q)^{-2}$$

$$+\left(-\frac{3265}{128}+\frac{3345}{32}\gamma^2-\frac{7089}{256}e^2-\frac{48225}{256}e'^2\right)m^4(1+Q)^{-2}$$

$$+\left(-\frac{243925}{2048}+\frac{175425}{256}\gamma^2-\frac{167835}{2048}e^2-\frac{1502265}{1024}e'^2\right)m^5(1+Q)^{-4}$$

$$+\left(-\frac{12626759}{24576}\right)m^6(1+Q)^{-}$$

$$+\left(-\frac{1365131021}{589824}\right)m^7(1+Q)^{-7}$$

(Observe that writing herein $Q=0$, and omitting the terms in m^4 and m^5 in the coefficient of $(1+Q)^{-1}$, and the term in m^5 in the coefficient of $(1+Q)^{-2}$, we have the original formula of p. 237)

$$g=nt\left\{\left[\frac{45}{16}m^2+\frac{585}{32}m^3\right]\frac{a^2}{a'^2}\right.$$

$$+\left\{\begin{array}{l}\left(\frac{3}{2}-\frac{15}{2}\gamma^2+\frac{9}{8}e^2+\frac{9}{4}e'^2-\frac{45}{4}\gamma^4+15\gamma^2e^2-\frac{45}{4}\gamma^2e'^2-\frac{27}{64}e^4+\frac{27}{16}e^2e'^2+\frac{45}{16}e'^4\right)m^2\\ \qquad+\left(-\frac{855}{128}\gamma^2+\frac{729}{512}e^2\right)m^4\\ \qquad+\left(\frac{1935}{256}\gamma^2-\frac{23355}{1024}e^2\right)m^5\end{array}\right\}(1+Q)^{-1}$$

$$+\left\{\begin{array}{l}\left(\frac{27}{4}-\frac{351}{16}\gamma^2-\frac{297}{64}e^2+\frac{401}{16}e'^2+\frac{135}{2}\gamma^4-\frac{1053}{32}\gamma^2e^2-\frac{1297}{16}\gamma^2e'^2+\frac{675}{256}e^4-\frac{1079}{64}e^2e'^2\right)m^3\\ \qquad+\left(-\frac{20007}{1024}\gamma^2-\frac{24057}{4096}e^2\right)m^5\end{array}\right\}(1+Q)^{-2}$$

$$+\left(\frac{1995}{64}-\frac{7989}{64}\gamma^2-\frac{9969}{256}e^2+\frac{29535}{128}e'^2\right)m^4(1+Q)^{-3}$$

$$+\left(\frac{17709}{128}-\frac{376653}{512}\gamma^2-\frac{440787}{2048}e^2+\frac{883245}{512}e'^2\right)m^5(1+Q)^{-4}$$

$$+\frac{2431349}{4096}m^6(1+Q)^{-5}$$
$$+\frac{62329307}{24576}m^7(1+Q)^{-6}$$

(where writing $Q=0$, and omitting the terms in m^4 and m^5 in the coefficient of $(1+Q)^{-1}$, and the term in m^5 in the coefficient of $(1+Q)^{-2}$, we have the original formula of p. 237). And

$$h=nt\Big\{\Big[-\frac{45}{32}m^2-\frac{1935}{512}m^3\Big]\frac{a^2}{a'^2}$$
$$+\left\{\begin{array}{l}\Big(-\frac{3}{4}+\frac{3}{2}\gamma^2-\frac{3}{2}e^2-\frac{9}{8}e'^2-\frac{51}{8}\gamma^2e^2+\frac{9}{4}\gamma^2e'^2+\frac{21}{64}e^4-\frac{9}{4}e^2e'^2-\frac{45}{32}e'^4\Big)m^2\\ \qquad+\Big(\frac{171}{128}\gamma^2-\frac{243}{128}e^2\Big)m^4\\ \qquad+\Big(-\frac{387}{256}\gamma^2+\frac{7785}{256}e^2\Big)m^5\end{array}\right\}(1+Q)^{-1}$$
$$+\left\{\begin{array}{l}\Big(\frac{9}{32}-\frac{27}{16}e^2-\frac{189}{32}\gamma^2+\frac{23}{32}e'^2+\frac{27}{16}\gamma^4+\frac{567}{16}\gamma^2e^2-\frac{99}{16}\gamma^2e'^2-\frac{675}{256}e^4-\frac{349}{16}e^2e'^2\Big)m^3\\ \qquad+\Big(-\frac{1559}{1024}\gamma^2-\frac{15309}{2048}e^2\Big)m^5\end{array}\right\}(1+Q)^{-2}$$
$$+\Big(\frac{177}{128}-\frac{195}{64}\gamma^2-\frac{699}{32}e^2+\frac{2685}{256}e'^2\Big)m^4(1+Q)^{-3}$$
$$+\Big(\frac{10949}{2048}-\frac{6369}{512}\gamma^2-\frac{133839}{1024}e^2+\frac{75759}{1024}e'^2\Big)m^5(1+Q)^{-4}$$
$$+\frac{467977}{24576}m^6(1+Q)^{-5}$$
$$+\frac{26983045}{589824}m^7(1+Q)^{-6}$$

(where writing $Q=0$, and omitting the terms in m^4 and m^5 in the coefficient of $(1+Q)^{-1}$, and the term in m^5 in the coefficient of $(1+Q)^{-2}$, we have the original formula of p. 238). We hence have

$$l=nt\{A+(1+B)Q+CQ^2\},$$
$$=nt\{A+Q+BQ+CQ^2\},$$
$$g=nt\{A'+B'Q+C'Q^2\},$$
$$h=nt\{A''+B''Q+C''Q^2\},$$

where (omitting the terms in $\frac{a^2}{a'^2}$)

$$A = 1 + \left(-\frac{7}{4} + \frac{21}{2}\gamma^2 - \frac{3}{4}e^2 - \frac{21}{8}e'^2 + \frac{33}{4}\gamma^4 - \frac{39}{8}\gamma^2 e^2 + \frac{63}{4}\gamma^2 e'^2 - \frac{9}{8}e^2 e'^2 - \frac{109}{32}e'^4\right)m^2$$
$$+ \left(-\frac{225}{32} + \frac{81}{4}\gamma^2 - \frac{675}{64}e^2 - \frac{825}{32}e'^2 - \frac{243}{4}\gamma^4 + \frac{1863}{32}\gamma^2 e^2 + \frac{629}{8}\gamma^2 e'^2 + \frac{2025}{256}e^4 - \frac{105}{32}e'^4\right)m^3$$
$$+ \left(-\frac{3265}{128} + \frac{14577}{128}\gamma^2 - \frac{1833}{64}e^2 - \frac{48225}{256}\right)m^4$$
$$+ \left(-\frac{243925}{2048} + \frac{177333}{256}\gamma^2 - \frac{328065}{4096}e^2 - \frac{1502265}{1024}e'^2\right)m^5$$
$$+ \left(-\frac{12626759}{24576}\right)m^6$$
$$+ \left(-\frac{136513021}{589824}\right)m^7.$$

$$B = \left(\frac{7}{4} - \frac{21}{2}\gamma^2 + \frac{3}{4}e^2 + \frac{21}{8}e'^2\right)m^2$$
$$+ \left(\frac{225}{16} - \frac{81}{2}\gamma^2 + \frac{675}{32}e^2 + \frac{825}{16}e'^2\right)m^3$$
$$+ \frac{9795}{128}m^4$$
$$+ \frac{243925}{512}m^5.$$

$$C = -\frac{7}{4}m^2$$
$$- \frac{675}{32}m^3.$$

$$A' = \left(\frac{3}{2} - \frac{15}{2}\gamma^2 + \frac{9}{8}e^2 + \frac{9}{4}e'^2 - \frac{45}{4}\gamma^4 + 15\gamma^2 e^2 - \frac{45}{4}\gamma^2 e'^2 - \frac{27}{16}e^4 + \frac{27}{16}e^2 e'^2 + \frac{45}{16}e'^4\right)m^2$$
$$+ \left(\frac{27}{4} - \frac{351}{16}\gamma^2 - \frac{297}{64}e^2 + \frac{401}{16}e'^2 + \frac{135}{2}\gamma^4 - \frac{1053}{32}\gamma^2 e^2 - \frac{1297}{16}\gamma^2 e'^2 + \frac{675}{256}e^4 - \frac{1079}{64}e^2 e'^2\right)m^3$$
$$+ \left(\frac{1995}{64} - \frac{16833}{128}\gamma^2 - \frac{19209}{512}e^2 + \frac{29535}{128}e'^2\right)m^4$$

$$+\left(\frac{17709}{128}-\frac{765573}{1024}\gamma^2-\frac{999051}{4096}e^2+\frac{883245}{512}e'^2\right)m$$
$$+\frac{2431349}{4096}m^6$$
$$+\frac{62329307}{24576}m^7.$$

$$B'=\left(-\frac{3}{2}+\frac{15}{2}\gamma^2-\frac{9}{8}e^2-\frac{9}{4}e'^2\right)m^2$$
$$+\left(-\frac{27}{2}+\frac{351}{8}\gamma^2+\frac{297}{32}e^2-\frac{401}{8}e'^2\right)m^3$$
$$-\frac{5985}{64}m^4$$
$$-\frac{17709}{32}m^5$$

$$C=\frac{3}{2}m^2$$
$$+\frac{81}{4}m^3.$$

$$A''=\left(-\frac{3}{4}+\frac{3}{2}\gamma^2-\frac{3}{2}e^2-\frac{9}{8}e'^2-\frac{51}{8}\gamma^2e^2+\frac{9}{4}\gamma^2e'^2+\frac{21}{64}e^4-\frac{9}{4}e^2e'^2-\frac{45}{32}e'^4\right)m^2$$
$$+\left(\frac{9}{32}-\frac{27}{16}\gamma^2-\frac{189}{32}e^2+\frac{23}{32}e'^2+\frac{27}{16}\gamma^4+\frac{567}{16}\gamma^2e^2-\frac{99}{16}\gamma^2e'^2-\frac{675}{256}e^4-\frac{349}{16}e^2e'^2\right)m^3$$
$$+\left(\frac{177}{128}-\frac{219}{128}\gamma^2-\frac{3039}{128}e^2+\frac{2685}{256}e'^2\right)m^4$$
$$+\left(\frac{10949}{2048}-\frac{15825}{1024}\gamma^2-\frac{220707}{2048}e^2+\frac{75759}{1024}e'^2\right)m^5$$
$$+\frac{467977}{24576}m^6$$
$$+\frac{26983045}{589824}m^7$$

$$B'' = + \left(\frac{3}{4} - \frac{3}{2}\gamma^2 + \frac{3}{2}e^2 + \frac{9}{8}e'^2\right) m^2$$
$$+ \left(-\frac{9}{16} + \frac{27}{8}\gamma^2 + \frac{189}{16}e^2 - \frac{23}{16}e'^2\right) m^3$$
$$- \frac{531}{128} m^4$$
$$- \frac{10949}{512} m^5,$$

$$C'' = - \frac{3}{4} m^2$$
$$+ \frac{27}{32} m^3.$$

And in the terms B Q, B′ Q, B″ Q, we have

$$Q = \left(1 - \frac{9}{2}\gamma^2 + \frac{9}{8}e^2 + \frac{3}{2}e'^2\right) m^2$$
$$+ \left(\frac{27}{8}\gamma^2 + \frac{675}{32}e^2\right) m^3$$
$$- \frac{515}{64} m^4$$
$$- \frac{787}{32} m^5,$$

and in the terms C Q^2, C′ Q^2, C″ Q^2, simply $Q^2 = m^4$. Hence finally the required values of l, g, h, are

$$l = n t \left\{ 1 + \left[-\frac{45}{32} m^2 - \frac{7425}{512} m^3\right] \frac{a^2}{a'^2} \right.$$
$$+ \left(-\frac{3}{4} + 6\gamma^2 + \frac{3}{8}e^2 - \frac{9}{8}e'^2 + \frac{45}{4}\gamma^4 - \frac{69}{8}\gamma^2 e^2 + 9\gamma^2 e'^2 + \frac{3}{32}e^4 + \frac{9}{16}e^2 e'^2 - \frac{45}{32}e'^4\right) m^2$$
$$+ \left(-\frac{225}{32} + \frac{189}{8}\gamma^2 + \frac{675}{64}e^2 - \frac{825}{32}e'^2 - \frac{1107}{16}\gamma^4 - \frac{81}{32}\gamma\, e^2 + \frac{349}{4}\gamma^2 e'^2 + \frac{2475}{64}e^2 e'^2\right) m^3$$
$$+ \left(-\frac{4071}{128} + \frac{15852}{128}\gamma^2 + \frac{31605}{512}e^2 - \frac{61179}{256}e'^2\right) m^4$$
$$+ \left(-\frac{265193}{2048} + \frac{335402}{512}\gamma^2 + \frac{1483665}{4096}e^2 - \frac{175710}{1024}e'^2\right) m^5$$

$$+\left(-\frac{12822631}{24576}\right)m^6$$
$$+\left(-\frac{1273925965}{589824}\right)m^7,$$

$$g = nt\left\{\left[\frac{45}{16}m^2+\frac{585}{32}m^3\right]\frac{a^2}{a'^2}\right.$$
$$+\left(\frac{3}{2}-\frac{15}{2}\gamma^2+\frac{9}{8}e^2+\frac{9}{4}e'^2-\frac{45}{4}\gamma^4+15\gamma^2e^2-\frac{45}{4}\gamma^2e'^2-\frac{27}{64}e^4+\frac{27}{16}e^2e'^2+\frac{45}{16}e'^4\right)m^2$$
$$+\left(\frac{27}{4}-\frac{351}{16}\gamma^2-\frac{297}{64}e^2+\frac{401}{16}e'^2+\frac{135}{2}\gamma^4-\frac{1053}{32}\gamma^2e^2-\frac{1297}{16}\gamma^2e'^2+\frac{675}{256}e^4-\frac{1079}{64}e^2e'^2\right)m^3$$
$$+\left(\frac{1899}{64}-\frac{15009}{128}\gamma^2-\frac{20649}{512}e^2-\frac{28959}{128}e'^2\right)m^4$$
$$+\left(\frac{15981}{128}-\frac{663621}{1024}\gamma^2-\frac{1152843}{4096}e^2+\frac{847213}{512}e'^2\right)m^5$$
$$+\frac{2103893}{4096}m^6$$
$$+\frac{52802843}{24576}m^7,$$

$$h = nt\left\{\left[-\frac{45}{32}m^2-\frac{1935}{512}m^3\right)\frac{a^2}{a'^2}\right.$$
$$+\left(-\frac{3}{4}+\frac{3}{2}\gamma^2-\frac{3}{2}e^2-\frac{9}{8}e'^2-\frac{51}{8}\gamma^2e^2+\frac{9}{4}\gamma^2e'^2+\frac{21}{64}e^4-\frac{9}{4}e^{2\,\prime 2}-\frac{45}{32}e'^4\right)m^2$$
$$+\left(\frac{9}{32}-\frac{27}{16}\gamma^2-\frac{189}{32}e^2+\frac{23}{33}e'^2+\frac{27}{16}\gamma^4+\frac{567}{16}\gamma^2e^2-\frac{99}{16}\gamma^2e'^2-\frac{675}{256}{}^4-\frac{349}{16}e^2e'^2\right)m^3$$
$$+\left(\frac{273}{128}-\frac{843}{128}\gamma^2-\frac{2739}{128}e^2+\frac{3261}{256}e'^2\right)m^4$$
$$+\left(\frac{9797}{2048}-\frac{7185}{1024}\gamma^2-\frac{165411}{2048}e^2+\frac{73423}{1024}e'^2\right)m^5$$
$$+\frac{199273}{24576}m^6$$
$$+\frac{66557733}{589824}m^7,$$

which values satisfy, as they should do, the equation $l + g + h = nt$. I recall that the precise signification of the constants is as follows:—n is the coefficient of t in the expression of the Moon's longitude in terms of the time, a the corresponding elliptic value of the mean distance ($n^2 a^3 =$ sum of masses), e the excentricity, such that in the expression of the longitude the coefficient of the leading term of the equation of the centre has its elliptic value

$$= 2e - \frac{1}{4}e^3 + \frac{5}{96}e^5$$

and γ the sine of the half-inclination, such that in the expression of the latitude the coefficient of the leading term has its elliptic value

$$= 2\gamma - 2\gamma e^2 - \frac{1}{4}\gamma^5 + \frac{7}{32}\gamma e^4 + \frac{1}{4}\gamma^5 e^2 - \frac{5}{144}\gamma e^6$$

n', a' are the mean motion and mean distance of the Sun, $m = \frac{n'}{n}$, and e is the excentricity of the Sun's orbit, considered as constant.

Extract of a Letter from Dr. B. A. Gould to the Astronomer Royal, dated Cordoba, Sept.* 30, 1871.

"Our work here has prospered as well as is consistent with the absolute impossibility of beginning it. That is to say, although the Observatory is, up to this present day, twelve and a half months after my arrival, not yet sufficiently complete to enable the instrumental observations for which I came here to begin, the Uranometry has more than fulfilled my most earnest hopes, and has enabled us to work very hard to useful purpose. Between the South Pole and +10° North Declination I have a catalogue of over 7100 stars visible to the naked eye on good nights, reaching to the magnitude which I am at present provisionally designating as 6·6 mag. All these stars have either been identified in the Catalogues or found not to be contained therein, and all their places have been referred to the mean equinox of our adopted epoch. And the magnitudes of all have already been so fully studied that I believe the mean error of the determinations cannot well exceed 0·1 mag. There are relatively few which have not been determined at least twice, and for the majority there are at least four determinations of magnitude, and of course by more than one observer in every case. Another month ought to complete the work of cataloguing and identifying, and of excluding such as, although they have been seen on favourable nights, are below the inferior limit which I have fixed

* Argentine Republic, about Lat. 31° S.—*Ed.*

upon. Then the work of mapping, of determining the places with greater accuracy, and of revising, will be a matter of simple routine.

"Of course a few variables have come to light, the observations on which I hope soon to have arranged in form for transmission to the *Astronomische Nachrichten* or the Royal Astronomical Society for publication. One has a period of only 21 hours, and though varying through less than a single magnitude, is so near the limit of unaided vision that it oscillates between visibility and invisibility. This is in *Triangulum Australis*. Another which likewise fluctuates through a narrow compass on the two sides of the usual limit is in *Musca*, and has a period of 84 hours, more or less. I have also reason to believe that α, β, and ν *Octantis*, are all of them more or less variable.

"On the 17th October the Observatory is to be formally inaugurated, and I have good reason to believe that within a month from this day I shall be able to begin the work upon the Zones, which formed the real motive of my expedition hither.

"I have seen with some interest the various discussions in the *Monthly Notices* of the Royal Astronomical Society regarding the motion of η *Argûs* in its nebula, or rather regarding alleged changes of form in the nebula itself. Thus far I have only been able to use a portable telescope of about five inches aperture, placed upon the roof of my house. But such observations as I have been able to make, compared with the drawing in Sir J. Herschel's Cape Observations, have tended strongly to impress me with the conviction that the alleged change is altogether imaginary.

"How much I wish Maclear's observations had been accessible you may imagine."

Note on the Inferior Conjunction of Venus. By Capt. W. Noble.

On Sept. 26, I observed *Venus* $1^h\,37^m$, after she had passed her inferior conjunction. The state of the atmosphere was too bad to admit of any attempt at micrometrical measurements: but I estimated that her illuminated crescent occupied a little more than a third of her circumference. My chief reason, however, for putting this observation on record is that I quite failed to see the dark body of the planet, which under analogous conditions has always been visible enough before in a constricted field. Doubtless the wretched state of the air may have had something to do with it; but is it possible that the bright background (whatever it may be) on which *Venus* must be projected varies in lustre?

Occultations of Stars by the Moon, observed at Forest Lodge, Maresfield. By Capt. W. Noble.

1871, September 24.

ϕ Capricorni.

The star disappeared instantaneously at the Moon's dark limb at $22^h\,50^m\,33^s{\cdot}5$ L.S.T.$=10^h\,37^m\,18^s{\cdot}14$ L.M.T. Power 154 adjusted on the star. I did not observe the reappearance. The atmospheric undulation was tremendous.

1871, October 23.

τ^1 Aquarii.

The star disappeared instantaneously at the Moon's dark limb at $22^h\,49^m\,44^s$ L.S.T.$=8^h\,42^m\,27^s{\cdot}5$ L.M.T., and reappeared at her bright limb somewhere about $23^h\,23^m\,56$ L.S.T.$=9^h\,16^m\,34^s$L.M.T. It was, however, several seconds after this the star was caught at a little distance from the Moon's limb; but the motion of the Moon was, so to speak, so oblique to the parallel of the star's declination, and the definition was so awful from great atmospheric disturbance, that I put this down with much hesitation.

τ^2 Aquarii.

This star, a much more conspicuous one than the previous object, disappeared instantaneously at the Moon's dark limb at $23^h\,57^m\,27^s{\cdot}8$ L.S.T.$=9^h\,50^m\,0^s{\cdot}2$ L.M.T.; and reappeared, pretty sharply, at the bright limb at $1^h\,7^m\,29^s{\cdot}8$ L.S.T.$=10^h\,59^m\,50^s{\cdot}7$ L.M.T.

The Moon's limb was very mountainous and uneven where the star reappeared; and the bubbling and boiling were as bad as, or worse than, ever.

Power 255 adjusted on the stars respectively.

1871, *Nov.* 10.

Self-recording Transit Micrometer. By A. S. Herschel, B.A., F.R.A.S.

Supposing that, in the annexed figure, the motion of a vertical micrometer wire, *a b*, can be adjusted exactly to that of a star in the field of view of a transit instrument, the following automatic arrangement affords the means of chronographically recording the transit of the wire, or of the star, across any moderate number of imaginary fixed vertical wires, at any convenient distances from each other in the field of view. The principal object endeavoured to be realized in the contrivance is that it may be reversible, or equally effective in its action whether the motion of the wire is from right to left, as in observing a star below the pole, or, as in the case of a star's transit above the pole, when the wire moves in the opposite direction. This condition was, however, not the only object kept in view, and believed to be satisfactorily fulfilled in its construction. The principle successfully adopted by Sir Joseph Whitworth to measure extremely small intervals of length (not exceeding the millionth part of an inch),

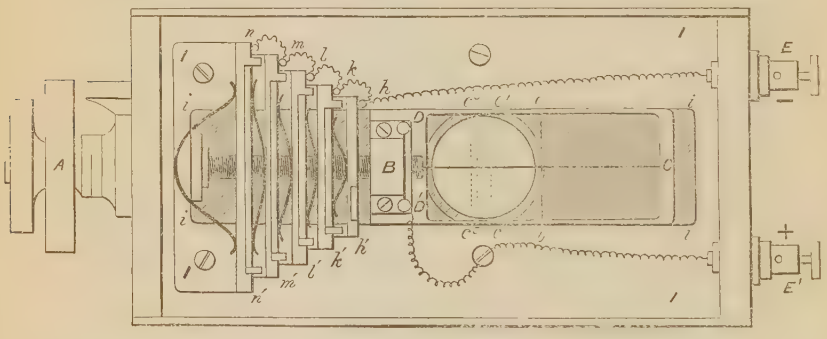
by substituting for the ordinary comparisons of divided scales with the length to be measured, by the eye (however well assisted by microscopes), the use of end-contacts only (tested by a peculiar contrivance) with a measuring-screw, while it suggested this arrangement of a self-recording micrometer-frame, seems to be equally well adapted, if the occurrence of contact between two metals can be noted with the same precision by a galvanic current as it can be recognised by mechanical means, to meet the necessary requirements of astronomical exactness.

In Whitworth's measuring instrument, a small metal plate, called a "gravity-piece," whose sides are perfectly parallel and true planes, is inserted between the face of the micrometer-screw and the end opposite to it of the bar whose length is to be measured, these faces being also wrought to parallel and true planes. The support of the gravity-piece between them, by friction, by advancing the screw until the first pressure is just sufficient to prevent it from falling out by its own gravity, affords such an exact test of the degree of mechanical contact existing between the bar and its end-bearings, that when the screw is withdrawn *one millionth part of an inch*, the support is so much loosened that the gravity-piece falls out. The present automatic contrivance may be described as a series of "gravity-pieces" (one for each imaginary transit-wire crossed by the star), whose successive contacts with two bearing-pins in the micrometer frame, and with each other, are made to record the instants of their occurrence by a momentary galvanic current, which will, perhaps, be as brief as that produced by a tap with the finger on a transmitting key, conveying the usual signal to the revolving cylinder of a chronograph. It should be mentioned that the original plan suggested itself to the writer rather as fulfilling the above conditions than from any previous knowledge or trial of experiments on what may be the practical efficiency of the kind of contact levers proposed to be used in it, either to transmit a momentary current of sufficient strength, or to preserve their touching surfaces, and the resulting relative distances between their surfaces unimpaired by frequent use. Difficulties of this kind, although evidently of the first consideration and importance, will yet, it is believed, not present insuperable obstacles to the adoption of some similar mechanical contrivance for transmitting galvanic signals, and for thereby automatically recording transits by the customary chronographic means.

The accompanying figure represents the interior of the micrometer (the front, or eye-plate, having been removed); A B is the micrometer-screw; and B C the wire-frame, to which it gives motion, furnished with horizontal wire, B C, and with a single vertical wire, *a b*. By the motion of the wire-frame the vertical wire, *a b*, is supposed, in the figure, to be carried from right to left, across the field of view, accompanying the image of a star, which it is made constantly to bisect, by means of a proper motion supposed to be imparted to the micrometer-screw, and thence to

the wire-frame, in the same direction. The dotted lines, $c_1 c_1$, $c_5 c_5$, in the middle of the field of view, represent the imaginary transit wires, or the positions of the movable wire at the instants of its passage across them which it is desired to record chronographically.

The description of the other essential parts of the instrument is as follows:—I I I I is an ivory plate, about an eighth of an inch thick, firmly fixed in the micrometer-box, so as (with the exception of the longitudinal slit, *i i i i*, along its centre) to cover without impeding the motion of the wire-frame and other parts in its interior. In the portion, *i i n n' h h'*, of its surface it contains a recess or depression in its thickness, of the form shown in the figure, to receive the movable and sliding contact-bars, *n n'*, *m m'*, *l l'*, *k k'*, *h h'*, each of which is shown in the figure in its position of rest, supported at its ends against the fixed, step-like bearings in the sides of the recess; and pressed against these supports by slender springs, placed between them, one of which, at the end nearest to the micrometer-screw-head, also presses



against the inner side of the recess at that end of the micrometer-box. These bars should be of platinum, about one line in thickness, and held down in their recess by a second plate, or thin cover of ivory, placed over them. They are also provided with a projecting part, along their lower side (not shown in the figure), fitting into the longitudinal slit, *i i i i*, of the principal ivory plate, by which they are guided in their sliding motion when the springs are compressed, and are enabled to return exactly to their proper bearings when the springs are again released. At the points *h*, *k*, *l*, *m*, *n* small platinum pins are inserted in the ivory steps, forming metallic surfaces, upon which the ends of the platinum sliding-bars press, in their position of rest; and these ends are thus all placed in galvanic connection (through the loops of a single insulated wire, *n h* E) with one terminal, E, of the arrangement. The remaining portion of each bar is completely insulated; and galvanic communication between them, through the hair-springs, is avoided by facing the front of each bar, as represented in the figure, with a thin plate of ivory, which is also continued in a

small tooth or projection at the ends k', l', m', n'; while the corresponding projections at the ends k, l, m, n are of the same metal as the bars; and are destined to be the only means of metallic contact, and of electrical communication between them. Only a part of the front bar $h\,h'$, near the end h', is similarly covered with a thin plate of ivory, and it is thus protected from metallic contact, at that point, with one of two projecting pins D, D′, of platinum, inserted in the wire-frame of the micrometer. These pins must be made sufficiently strong and high to press together all the sliding bars towards the screw-end of the micrometer, when the motion of the screw causes the wire frame and the movable wire $a\,b$ to cross the field of view from right to left. The slender extension-springs between the bars are so graduated in strength that the first, which is fastened to the bar $h\,h'$, *will be completely compressed*, and that bar *will come in contact with the projecting points, k, k' of the next bar* before the spring attached to the latter bar is affected. The second spring will then be compressed in its turn, without affecting the third, until the second bar touches and presses the third bar from its place, when the third spring will begin to be compressed; and so on in order. Since the pressure of the springs acts, in each case, upon the centre of the bars, it is evident that any greater pressure than this (like that of contact between the bars and the projecting point of the next following bar) acting in the opposite direction, *between the centre and one end of the bar*, will immediately cause that end of the bar to be lifted from its bearing. In this manner the contact of *the pin* D, *and of the ends h, k, l, m, n of the bars* with each other will be simultaneous with the removal *of those ends of the bars* from their bearings, so as to allow, at least, only an inappreciably small interval of time to elapse between the completion of the circuit through D, and the ends of the sliding-bars, from E′ to E, and its interruption at the next instant of time by the separation of the same end of the last bar of the row set in motion from the platinum pin placed there for its support. On the other hand, when the springs are released, by the motion of the screw and of the micrometer wire-frame in the opposite direction, the metallic communication completed between the terminals E E′ at the moment when any bar of the series falls in with its fixed metallic support, is, at the same instant, or at least in the next inappreciably small interval of time, broken by the opening of the bars at that end, produced by the expansion of the next spring in the advancing row.

When a star enters the field of view, and is accompanied across it by the movable wire, starting from the right, as in the figure, the poles E, E′ being connected respectively with a galvanic battery and with a chronographic-recording apparatus; on the arrival of the wire at $c_1\,c_1$, the pin D, coming into contact with the first bar $h\,h'$, and at the same time removing its end h from the platinum bearing on that point, causes a galvanic current of momentary duration to pass from the battery to the recording

instrument, conveying an impression, like that which is produced by a small tap of the finger on a transmitting key, to th revolving drum.

The wire having next advanced an interval equal to that contained between the bar $h\,h'$ and the projecting metallic part at k of the second bar $k\,k'$, a second current of the same kind will record the instant of contact between the first pair of bars, or the moment of the star's transit over the second imaginary vertical wire. After an interval corresponding to the distance between the second bar and the projecting part at l of the third bar, the moment of contact between this pair of bars will be similarly recorded, and the instant is that at which the star crossed the position of the central or third imaginary transit-wire. Advancing thus until the last pair of bars are made to touch each other, and the moment of the star's transit over the last imaginary wire $c_5\,c_5$ is thereupon recorded, the strongest extension-spring of the series, that acting upon the bar $n\,n'$ will then begin to be compressed, while the movable wire is carried in that direction to the furthest limit of the field of view. In this position, by an exactly reversed series of operations (when a star is observed above the pole, and the wire is driven by the screw in the opposite direction, following its motion), the instrument may be made to record automatically the times of passage of the star, or movable wire, over exactly the same positions of imaginary vertical wires in the field of view as those which it traversed when moving in the previous direction. It is at least important to observe that the *difference* from the same exact positions, thus oppositely obtained, may be expected to depend less upon want of mechanical accuracy in the construction (*durability of surfaces, rigidity of the bars and pins, and immobility of the bearing-points*, being supposed to be practically attainable), than upon the different sensibility of galvanic currents of ordinary strength (arising from the heat which they produce in their passage) to the exact moments of commencement, and interruption of mechanical contact between two surfaces of metal, which are first brought into contact by pressing them together, and are then separated by gradually withdrawing them from each other. With the use of feeble currents, and of a specially delicate recording-apparatus, like that recently exhibited to the British Association at Edinburgh, as introduced by Sir W. Thomson to record the very feeble currents despatched through long submarine cables; the condition of reversibility in its action being apparently fully satisfied, with the exception of a, perhaps needless, complexity, and consequent liability to derangement in its details, which a more ingenious mechanical disposition of its parts would not impossibly remove the remaining conditions of rapid precision in its signals, and of regularly recurring intervals between them appear to be, at least, provisionally, and, although less certainly, yet in the present form of a self-recording transit-micrometer, perhaps not quite inadequately fulfilled.

Nebulæ discovered and observed at the Observatory of Marseilles with the Foucault Telescope of 0·ᵐ80. By M. Stephan.

Mean Position for 1870.

R.A.	P.	Number and Comparison in R.A.	Number and Comparison in P.	Remarks.	Comparison Stars.
h m s	o ′ ″				
15 58 35·67	71 53 33·1	5	5	Group of 3 Nebulæ (1), (2), (3). All three very small and very faint, (2) is the least faint, (3) the most, (1) is diffused and attached to a very small star.	29,273 Lat. Herc.— 6
15 58 44·65	71 55 18·7	5	5		id.
15 58 48·81	71 56 31·6	5	5		id.
16 6 44·58	79 47 50·2	5	5	Round, small, very faint centre, more brilliant, but no nucleus.	73 Weisse, xvi. 9
16 18 28·76	48 45 41·5	5	5	Excessively faint, very small, round, more brilliant in the middle.	2,821 Arg. Z. + 41° 9, 2
16 23 24·59	56 54 5·0	5	5	Group of 3 nebulæ (1), (2), (3). Excessively small and faint, a little more brilliant towards the middle.	5,515 B. A. C. 7½
16 23 25·51	56 51 38·8	5	5		id.
16 23 32·35	56 51 52·2	5	5	(1) and (3) are nearly equal. (2) a little less faint.	id.
16 39 0·75	49 56 57·6	3	3	Scarcely observable.	1,225 Weisse, xvi. 9
16 46 42·04	87 27 48·7	5	5	Excessively faint, vaporous, irregularly round, edges very undecided. $D_S^N = 58''$ $D_E^W = 2' 22''$	5,625 B. A. C. 7½
16 51 31·67	61 58 0·8	5	5		2,649 Arg. Z. + 28° 9, 1
16 52 4·81	61 56 23·5	5	5	Group of 5 nebulæ, (1), (2), (3), (4), (5), excessively small and faint.	id.
16 52 17·70	61 56 50·7	5	5		id.
16 52 46·78	61 56 17·7	5	5	Order of brightness (increasing). (4), (1), (3), (5), (2).	id.
16 53 32·98	61 56 9·6	5	5		id.
16 55 17·62	66 45 47·8	3	3	Group of 3 nebulæ (1), (2), (3). (1) is extremely faint, no brilliant point; (2) is nearly imperceptible; and (3) is a small nucleus tolerably brilliant, surrounded by a very faint nebulosity: this last seems identical with 4,266 J. F. W. Herschel, of which the position furnished by the catalogue would be a little erroneous.	1,717 Weisse, xxvi. 9
16 55 21·30	66 46 6·9	3	3		id.
16 55 22·81	66 47 45·8	3	3		id.
17 8 48·36	69 31 59·7	5	5	Almost imperceptible, irregularly round and a little less faint towards the centre, edges very indistinct. D = 40″ about.	283 Weisse, xvii. 8
17 26 6·71	82 50 30·8	5	5	Round, small, faint, more brilliant in the middle.	32,068 Lat. 8
17 33 7·09	71 2 44·6	5	5	Very faint, edges badly defined, irregularly round, a brilliant point towards the centre. D = 55″ about.	1,080 Weisse, xvii. 9
17 34 40·27	77 18 22·5	3	3	Extremely small and faint, a small nucleus surrounded by a nebulosity.	α Ophiuchus.
17 38 58·98	64 25 49·8	5	5	Round, very small and very faint.	3,330 Arg. Z. + 25° 9, 3
17 46 59·27	58 30 14·3	5	5	Round, edges badly defined, extremely faint. Extremely small gradually brilliant towards the centre.	3,118 Arg. Z. + 31° 9, 5
17 48 48·58	71 35 54·2	5	5	Groups of 2 nebulæ (1) and (2). (1) extremely small, very faint, round, gradually brilliant towards the middle; (2) like the preceding, but a little less faint.	1,601 W. xvii. 7, 8
17 49 8·77	71 38 52·9	5	5		id.

Mean Position for 1870.

R.A.	P.	Number and Comparison in R.A.	P.	Remarks.	Comparison Stars.	
h m s	° ′ ″					
17 54 15·64	65 6 12·1	5	5	Very small and very faint nucleus of 15th Mag.	33,103 Lat.	8
18 7 15·14	64 22 41·6	2	2	Scarcely visible. A vaporous aspect comprised between two very small stars.	33,555 Lat.	8
18 29 9·76	67 11 22·5	5	5	Extremely small and faint, round, gradually brilliant towards the middle.	34,322 Lat.	7½
18 29 32·50	59 22 47·8	5	5	Extremely small and faint.	896 W. xviii.	9
18 32 11·95	63 41 34·8	5	5	Nucleus of 14th Mag. surrounded by a very faint nebulosity.	993 W. xviii.	9
18 33 15·35	64 44 11·9	5	5	A small nucleus, very faint, surrounded by a tolerably extensive nebulosity, round, the edges badly defined.	34,510 Lat.	8½
18 36 6·39	53 45 12·3	5	5	Round, tolerably extended, excessively faint on the edges, a brilliant point.	3,224 Arg. Z. + 36°	9, 3
18 45 19·95	63 18 50·1	5	5	Excessively small and faint, round, edges badly defined, condensation in the centre.	3,360 Arg. Z. + 26°	9, 3
18 58 16·48	68 34 54·4	5	5	Excessively small, tolerably brilliant, brilliant points towards the centre.	22 W. xix.	8
19 6 5·05	59 39 59·7	5	5	Round, small, tolerably brilliant, more brilliant in the middle, seems resolvable.	35,989 Lat.	6½
20 32 8·73	95 25 32·1	5	5	Small, round, whitish, moderately brilliant, more brilliant towards the centre.	39,827 Lat.	6
21 56 44·03	79 25 41·1	5	5	Irregularly round, very small, extremely faint, scarcely observable, towards the centre a little less faint.	42,973 Lat.	7
22 5 34·36	64 46 35·1	5	5	Round, small, very faint, vaporous aspect.	96 W. xxii.	8, 9
22 31 7·30	52 7 30·7	3	3	Small, moderate brightness, more brilliant towards the centre, egg-shaped.	772 W. xxii.	8

Mean Position for 1870.

Comparison Stars.		R. A.	P.
		h m s	° ′ ″
29,273 Lat.	6	15 57 58·92	71 50 19·1
73 W. xvi.	9	16 5 27·19	79 47 36·9
2,821 Arg. Z. + 41°	9, 2	16 17 7·32	48 49 20·3
5,515 B. A. C.	7½	16 23 1·38	57 0 33·1
1,225 W. xvi.	9	16 39 16·47	49 50 14·0
5,625 B. A. C.	7½	16 14 20·83	87 31 21·3
2,649 Arg. Z. + 28°	9, 1	16 55 57·19	61 56 11·4
1,717 W. xvi.	9	16 56 33·25	66 52 38·5
283 W. xvii.	8	17 11 20·48	69 31 6·4
32,068 Lat.	8	17 29 46·81	82 53 54·4
1,080 W. xvii.	9	17 34 30·12	71 3 29·7
α Ophiuchus		17 28 53·95	77 20 35·6
3,330 Arg. Z. + 25°	9, 3	17 37 28·70	64 29 41·9

Mean Position for 1870.

Comparison Stars.		R.A. h m s	P. ° ′ ″
3,118 Arg. Z. + 31°	9, 5	17 48 37·31	58 32 45·3
1,601 W. xvii.	7, 8	17 50 42·25	71 39 8·3
33,103 Lat.	8	17 56 15·86	65 1 51·7
33,555 Lat.	8	18 7 47·69	64 23 37·9
34,322 Lat.	7½	18 26 0·28	67 6 19·8
896 W. xviii.	9	18 30 42·79	59 26 35·9
993 W. xviii.	9	18 33 39·29	63 41 25·0
34,510 Lat.	8½	18 30 27·23	64 44 6·8
3,224 Arg. Z. + 36°	9, 3	18 35 17·46	53 47 38·2
3,360 Arg. Z. + 26	9, 3	18 42 5·75	63 19 11·5
22 W. xix.	8	19 2 35·01	68 25 28·9
35,989 Lat.	6½	19 4 21 42	59 38 34·0
39,827 Lat.	6	20 32 13·92	95 22 59·3
42,973 Lat.	7	21 56 6·57	79 15 22·8
96 W. xxii.	8, 9	22 4 53·92	64 49 29·9
772 W. xxii.	8	22 33 42·78	51 55 40·1

Observations of Encke's Comet with the Transit Circle and the Great Equatoreal at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

1871.	G.M.T.	Observed R.A.	Correction to Mr. Hind's Ephemeris.	Observed N.P.D.	Correction to Mr. Hind's Ephemeris.	Observer.
	d h m s	h m s	s	° ′ ″	″	
Nov. 8	6 28 43	21 38 42·5	+11·0	..	..	J.C.
	6 28 48	21 38 47·1	+15·6	56 54 27·0	+49·0	P.
	9 6 15 7	21 29 0·9	+18·8	57 48 7·0	−17·0	J.C.

The observations were made by Mr. Carpenter and Mr. Potts.

Note by Mr. Carpenter:—"Nov. 9. The comet was large and faint, the diameter of the brightest portion equal to one interval of the wires used in eye-and-ear observations (about 240″). It was somewhat fan-shaped, with no nucleus; the part observed being that which I judged the brightest. The low-power eye-piece (about 50) was used."

In the first observation, on November 8, the transit was observed over two of the vertical wires, and in the second observation over one only. On November 9 the transit was observed over six wires.

Mr. Carpenter further writes: "I observed this comet last night, Nov. 9, with the Great Equatoreal (as well as with the Transit Circle). The appearance was the same as on the pre-

vious evening; but I was able to make out a considerable extension of the illumination beyond the bright fan-shaped condensation, but on one side (the spreading side) only. On the opposite side this diffused illumination appeared to be cut off nearly in a straight line immediately behind (following) the apex of the fan. (*See woodcut.*)

"The axis of the illuminated fan was inclined about 5° or 10° to the plane, the apparent west side (apex of the fan) dipping. The comet was easily seen in the finder of the Great Equatoreal."

1871, *Nov.* 10.

[The Astronomer Royal explained to the Meeting, by reference to a globe upon which the Sun and the Comet had been drawn in their proper positions, that the spreading side of the fan-shaped luminosity was turned almost directly towards the Sun.]

*Ephemeris of Encke's Comet.**

At Greenwich Midnight.

1871.	R.A. h m s	N.P.D. ° ′	Log. of Hor. Parallax.
Nov. 1	22 45 51	52 27·1	1·3943
2	22 36 6	52 54·2	1·4023
3	22 26 13	53 25·5	1·4098
4	22 16 16	54 1·0	1·4169
5	22 6 15	54 40·9	1·4234
6	21 56 13	55 25·1	1·4293
7	21 46 12	56 13·6	1·4346
8	21 36 13	57 6·1	1·4394
9	21 26 19	58 2·3	1·4436
10	21 16 32	59 2·3	1·4471
11	21 6 53	60 5·8	1·4501
12	20 57 22	61 12·5	1·4524
13	20 48 1	62 22·3	1·4541
14	20 38 51	63 34·5	1·4552
15	20 29 52	64 48·8	1·4556
16	20 21 5	66 5·0	1·4555
17	20 12 31	67 22·9	1·4548
18	20 4 8	68 42·1	1·4535
19	19 55 57	70 2·3	1·4516
20	19 47 58	71 23·3	1·4491
21	19 40 11	72 44·7	1·4460
22	19 32 34	74 6·6	1·4424
23	19 25 9	75 28·2	1·4383
24	19 17 54	76 49·7	1·4337
25	19 10 48	78 10·9	1·4286
26	19 3 52	79 31·7	1·4236
27	18 57 5	80 51·9	1·4169
28	18 50 26	82 11·4	1·4103
29	18 43 56	83 29·9	1·4032
30	18 37 35	84 47·5	1·3957
Dec. 1	18 31 21	86 4·3	1·3877
2	18 25 14	87 20·1	1·3793
3	18 19 15	88 34·8	1·3704
4	18 13 24	89 48·5	1·3611
5	18 7 41	91 1·1	1·3514

The perihelion passage is assumed, 1871, Dec. 28·77375,

* This Ephemeris and the following one of Tuttle's Comet, both communicated by Mr. Hind, have been issued as circulars.—Ed.

G.M.T., as indicated by an observation at Mr. Bishop's Observatory, on October 10.

The Sun's Equat. Hor. Parallax = 8″·91.

J. R. Hind.

Twickenham, 1871, *Oct.* 30.

Ephemeris of Tuttle's Comet.

At Greenwich Midnight.

1871.	R.A.	N.P.D.	Log. Δ.
	h m s	° ′	
Nov. 1	9 56 52	66 16·9	
2	9 59 4	67 39·5	9·9097
3	10 1 15	69 4·0	
4	10 3 24	70 30·5	9·8982
5	10 5 53	71 59·4	
6	10 7 41	73 30·7	9·8873
7	10 9 49	5 4·1	
8	10 11 57	76 39·7	9·8771
9	10 14 5	78 17·4	
10	10 16 13	79 57·1	9·8677
11	10 18 21	81 38·8	
12	10 20 29	83 22·5	9·8593
13	10 22 37	85 7·9	
14	10 24 46	86 55·0	9·8521
15	10 26 55	88 43·7	
16	10 29 5	90 33·8	9·8462
17	10 31 15	92 25·0	
18	10 33 26	94 17·4	9·8417
19	10 35 37	96 10·7	
20	10 37 50	98 4·7	9·8387
21	10 40 4	99 59·2	
22	10 42 19	101 53·8	9·8373
23	10 44 35	103 48·5	
24	10 46 53	105 42·9	9·8375
25	10 49 12	107 36·9	
26	10 51 33	109 30·3	9·8393
27	10 53 56	111 22·8	
28	10 56 21	113 14·3	9·8426
29	10 58 48	115 4·7	
30	11 1 17	116 53 6	9·8474

The ephemeris is calculated from Dr. Tischler's elements, but with perihelion passage corrected to December 1, 7974, G.M.T., by observations at Paris and Hamburg.

J. R. Hind.

Queries relative to Double Stars. By Sir J. W. F. Herschel, Bart.

The Committee appointed by the Council of Royal Astronomical Society to examine and report upon the valuable collection of papers bequeathed to the Society by the late Sir J. F. W. Herschel, entitled "General History of Double Stars," have requested that the following list of queries collected by him in the course of his laborious researches should be printed in the *Monthly Notices*, as an invitation to Astronomers furnished with good libraries and good telescopes to assist in the solution of the doubts respecting the stars contained in the list.

The list is given exactly as Sir John left it, without any attempt to diminish the number of doubtful cases by reference to Struve's *Positiones Mediæ*, or other works.

Star's Name.	R.A. h	m	s	N.P.D. °	′	″	
h 2021	1	0	37	109	31	40	Is it really close double?—"Violent suspicion."
Σ 168	1	40	17	20	47	30	Not seen double by h.
Σ 211	1	55	54	96	14	50	No such star found in, or near place by h.
Σ 343	2	55	23	6	35	32	Are these the same double star? Σ is confused, and h disagrees.
Σ 347		56	27	6	35	2	
Σ 407	3	21	56	101	43	4	? Is the minute of R.A. 19 or 21? Σ's two catalogues differ.
Σ′ 417	4	7	27	97	55	22	40 Eridani. Confusion exists. Wanted an exact diagram description, and measures of A, B, C; and ? of a 4th star, D.
Σ 518		7	48		54	23	
Σ 609	4	41	59	89	8	59	? Whether Struve's place, as here given from "Positiones Mediæ," or that of my 7th Catalogue $4^h\ 43^m\ 4^s$, 89° 3′ 17″ be right. Positions and distances agree. Or are they really two different double stars? *My place* is corroborated in 5th Catalogue, h 2240 *bis*, making the R.A. 43^m.
Σ 662	5	5	39	94	15	54	In Σ "Pos. Mediæ," the P.D. is 94° 15′ 54″; but in the Dorpat Catalogue and also in the "Mensuræ Micrometricæ," the degree of P.D. is 64°. The declination given are Dorp. + 25° 45′; "Mens. Microm." + 25° 45′; "Pos. Med." − 4° 15′ 54″.
				64			
h 5465	5	39	18	78	4	3	An excessively minute *comes* 12″ distant suspected. ? if verified.
Σ 923	6	22	15	30	25	8	? Which is the right minute of R.A.? Σ leaves it doubtful, and I have no observation of it.
		42	15				
Σ 1006	6	51	22	26	59	18	Which is the right P.D.? In the Dorpat Catalogue the declination is + 63° 1′; in the "Mens. Microm." + 62° 50′. Which is right?
				27	10	18	
Σ′(989) *g.c.*	8	14	22	92	25	7	Set down as "very near" σ 295 (Catalogi Prioris.) Are these really two different double stars? If not, which is right?
σ 295	8	14	25	92	23	51	
Σ 1259	8	32	7	51	5	29	In Dorpat Catalogue $8^h\ 31^m{\cdot}9$, Decl. + 38° 56′. In "Mens. Microm." $8^h\ 36^m$, Decl. + 39° 5′. Query which is right. h has no observation.
δ Cancri	8	35	1	71	13	39	h 457 makes Position 160°, Distance 25″; Lassell, "Astr. Nach." No. 858, states it as Position 121·°12, Distance 45″. What is it really?

Star's Name.	R.A. h	m	s	N.P.D. °	′	″	
∂ Cancri	12	29	–	75	17		Close to a star of 9th Mag. is a small, well-defined body, *which may be* a close double star. *n p* is a very faint nebula (no doubt III. 602, or Neb. No. 3113 of my general Catalogue.) ? Is it there still? Was it a planet?
ϰ Virginis	14	3	50	99	28	42	σ 453 (Catalogi Prioris.) Is it really a double star?
ω Boötis	14	54	40	64	18	58	σ 469. Is it really double?
h 1271	15	15	18	107	59	48	Are these identical; and if so, which P.D. (differing 1°) is the right? The measures agree.
h 4768	15	15	18	109	0	43	
h 256	15	32	2	71	40	0	Not found subsequently; but ? if properly looked for. Does it exist? Measures 5° *s.f.*; distance 2″.
Σ 2012	16	0	49	97	48	13	Is this really identical with B.A.C. 5379?
h 584	16	{7 13}	58	50	20	45	R.A. between 7ᵐ and 13ᵐ. ? The right minute.
Σ′ (1814)	16	16	48	88	23	2	"Loco 2041" Are these really two double stars? And if so, to which does the description, Position 4°·40, Distance 3ˢ·060, belong?
Σ 2041	16	16	48	88	21	35	
Mayer	17	1	29	114	2	43	Is there any double star in this place?
Σ 2190	17	29	±	68	53		The measures of this star are very conflicting. Σ (1829) makes Position 33°·22. h (1830), by a sweep, 18°·4 (plainly written in original, and diagram agreeing.) Mädler (1843), 33°·67; and Dembrowski (1863), 23°·00. Which is right?
H 4599	18	57	0	58	32	41	Query as to its existence in this place, or very near it.
Σ 2545	19	27	32	100	31	57	Smyth described this as "closely following" a star R.A. 19ʰ 27ᵐ 28ˢ, and the R.A. 19ʰ 27ᵐ 32ˢ given by him differs 2ᵐ from Σ. Which is right?
	19	29	23				
Σ′ (2360)	19	40	4	57	31	25	Are these not identical; the P.D. applied to H h 640 being 11′ wrong?
H 4640	19	39	54	57	19	48	
Σ 2634	20	1	50	73	41	46	Smyth identifies his No. 733 (Cycle) with this star, and with H h 668; but his P.D. 73°33′54″ (for 1830) differs 8′. Are these two double stars?
σ 680	20	22	53	79	23	3	Are these the same double star? Σ 2690 is identified with Dawes (1); h (269); H h 691; and O.Σ 407.
Σ 2690	20	23	6	79	18	22	
h 2994	20	36	18	112	7	33	17 Capricorni. Requires verification as a Position 338°·7, Distance 20″. A *very* minute companion.
h {1619 1620}	21	4	22	{76 77}	9 9	37 35	Are not these the same; but 1° P.D. mistaken in one or other? Which is right? 1620 is described as *quadruple*.
h 5517	21	14	54	103	36	6	18 *Aquarii*. Query a very minute companion preceding, at 13″ distance.
Σ 2792	21	15	42	61	46	6	Query if not the same, with 1° error in P.D. in one or other; and, if so, which is right?
h 1638	21	15	43	62	46	43	
h 935	21	19	20	{56 57}	28	26	Two observations differ by 1° P.D. Query which is right?
Σ 2827	21	38	54	28	{9 8}	54 39	"Loco Σ 2827." The latter star seems to be only the former, with its place better determined. Σ 2827 is a really existing double star =h 1690=Σ 2827 of the "Mens. Microm." Are those really two double stars very near each other? h 1690's place is 21ʰ 39ᵐ 32ˢ, N.P.D. 27° 11′ 1″.
Σ′ (2628)	21	39	5				

Star's Name.	R.A. h	m	s	N.P.D. °	′	″	
h 1761	22	16	24	16	0	38	Oblong. Requires re-examination.
h 5529	22	28	57	95	6	4	$\varkappa$ *Aquarii*. An excessively minute companion strongly suspected.
h 3158	22	53	15	20	8	37	Excessively close. Requires verification. Position 45°.
Sh 358 / σ 690	23	46 / 49	20 / 22	59	6 / 11	20 / 40	? If two distinct double stars. If only one, ? its place.

Note on a Pair of Differential Equations in the Lunar Theory.

By Prof. Cayley.

The equations

$$\frac{d}{dt}\frac{d\varrho}{dt} - \varrho\left(\frac{dv}{dt}\right)^2 + \frac{1}{\varrho^2} = km^2\varrho\left\{\frac{1}{2} + \frac{3}{2}\cos(2v - 2mt)\right\},$$

$$\frac{d}{dt}\,\varrho^2\frac{dv}{dt} = jm^2\varrho^2\left\{\frac{3}{2}\sin(2v - 2mt)\right\},$$

taking therein $j = k = 1$ in effect present themselves in the Lunar Theory, and particular integrals in series have been obtained, the development being carried to a great extent; but I give the results only as far as m^4, viz., writing

$$t - mt = \mathrm{D},$$

we have

$$v = t + \left(\frac{11}{8}m^2 + \frac{59}{12}m^3 + \frac{893}{72}m^4\right)\sin 2\,\mathrm{D} + \frac{201}{256}m^4\sin 4\,\mathrm{D},$$

$$1 = 1 + \frac{1}{6}m^2 + \frac{179}{288}m^4 + \left(m + \frac{19}{6}m^3 + \frac{131}{18}m^4\right)\cos 2\,\mathrm{D} + \frac{7}{8}m^4\cos 4\,\mathrm{D},$$

In the Lunar Theory j and k are properly each $= \frac{1}{1+\frac{\mathrm{E}}{m'}}$ (E the mass of the Earth, m' that of the Sun), but they are taken to be $= 1$; the numerical difference is inappreciable; but there would be a considerable theoretical advantage in retaining in the equations the coefficients j, k: in fact, the developments could then be arranged according to the powers of k, that is according to the powers of the disturbing force; whereas, when k is taken $= 1$, we have only a development in powers of m, and since m also presents itself through the coefficient $2 - 2m$ of t in $2v - 2mt$, terms which are really of different orders in regard to the disturbing force, are united together into a single term: in fact, instead of a term of the form $(\mathrm{A}k + \mathrm{B}k^2 + \&c.)\,m^v$, where A, B, are numerical,

we have the term $(A + B + \ldots)\, m^p$, where of course $A + B \ldots$ is given as a single numerical coefficient. There is no equal advantage in retaining the two coefficients k, j, as this only serves to show how a term arises from the central and tangential forces respectively; thus retaining these coefficients, the integrals as far as m^2 are

$$v = t + \left(\tfrac{1}{2}k + \tfrac{7}{8}j\right) m^2 \sin 2\,D,$$

$$\frac{1}{\varrho} = 1 + \tfrac{1}{6}m^2 k + \left(\tfrac{1}{2}k + \tfrac{1}{2}j\right) m^2 \cos 2\,D,$$

agreeing with the former result when $k = j = 1$; but there is, nevertheless, some interest in retaining the two coefficients. I hope to develope the results somewhat further, and to communicate them to the Society.

Observations of Comets from B.C. 611 *to* A.D. 1640, *extracted from the Chinese Annals, translated, with Introductory Remarks, and an Appendix comprising Tables for reducing Chinese Time to European Reckoning, and a Chinese Celestial Atlas.* By John Williams, F.S.A., Assistant-Secretary of the Royal Astronomical Society. London: Printed for the Author, by Strangeways and Walden. 4to, 1871.

The Author was, by a question put to him by Mr. Hind, led to examine Biot's Catalogue of Comets observed in China; and he quickly found that, although very accurate in its details, it was by no means so complete as could be wished, many comets being recorded in the "Encyclopædia" of Ma Twan Lin, and in the great historical work called the "She Ke," which are not noticed by Biot. It therefore occurred to him that a catalogue comprising the whole of the observations of the comets contained in the two Chinese works just referred to, translated from the original, and arranged chronologically, with an explanation of all the particulars connected with them, might be of service to astronomers, particularly to those engaged in cometary researches. The observations thus brought together amount to 373.

The introductory remarks comprise many interesting particulars relating to Chinese astronomy, and also instructions for the use of the chronological tables contained in the appendix, giving the succession of the dynasties and emperors from the earliest period to the present time; and of the other tables for finding the months, or moons, and days. The Appendix includes also a complete Chinese celestial atlas from an original work, so that the names and relative positions of the asterisms and stars can be readily found.

As this work has been privately printed by the Author, it forms no part of the publications of the Society. It can be obtained (at a reduced price to Fellows) by application to Mr. Williams at the rooms of the Society.